Well abandonment procedures and perforation with a slotted charge for cement squeeze applications

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WHAT IS AN ABANDONMENT ?

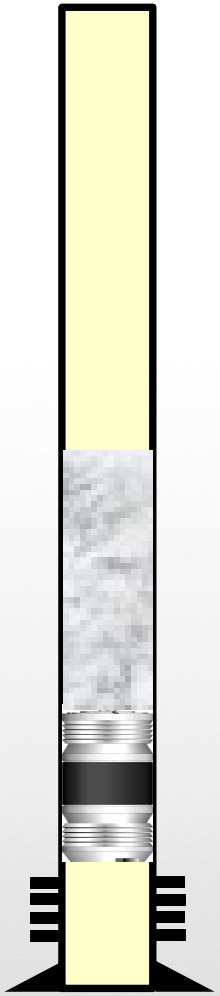
Permanent isolation of:

- groundwater formations of varying salinities outside casing from each other and from hydrocarbon formations and,
- porous hydrocarbon formations both inside and outside of casing, from each other and to surface.

Accomplished by multiple means including setting bridge plugs, permanent packers, remedial cementing operations and spotting cement plugs.

Surface recovery

- Casing strings must be cut off below ground level according to local regulations
- Casing strings must be capped with steel plates installed in a manner which will not allow pressure build up, but will stop access to casing



ABANDONMENT CATAGORIES & ISSUES

- Categories:
  - Open Hole
  - Cased Hole
  - Routine
  - Non Routine
- Potential Issues:
  - Base Ground Water Protection (BGWP)
  - Gas leaks
    - Sustained Annular Casing Gas (Surface Casing Vent Flow)
    - Gas Migration
  - Porosity Isolation

OPEN HOLE ABANDONMENTS

For the abandonment of an open-hole well, the licensee must set cement plugs of sufficient length and number to;

- cover all non-saline groundwater to the BGWP
- cover all porous zones to eliminate cross-flow

CASED HOLE ABANDONMENTS

Cased hole abandonments must

- Abandon each completed pool separately
- Ensure cement top in well covers both porosity intervals and ground water zones, if not:
  - Perform remedial cementing operations on porosity intervals and all non-saline groundwater and protected intervals as required

ROUTINE ABANDONMENTS

Routine well abandonment is a “normal” well abandonment that meets all regulatory criteria pertaining to:

- the type of well being abandoned
- the wells geographic location
- the impact of the well on any producing zones / wells
- the absence of a wellbore problem

NON ROUTINE ABANDONMENTS

Non-routine abandonment consists of operations that do not fall under routine requirements.

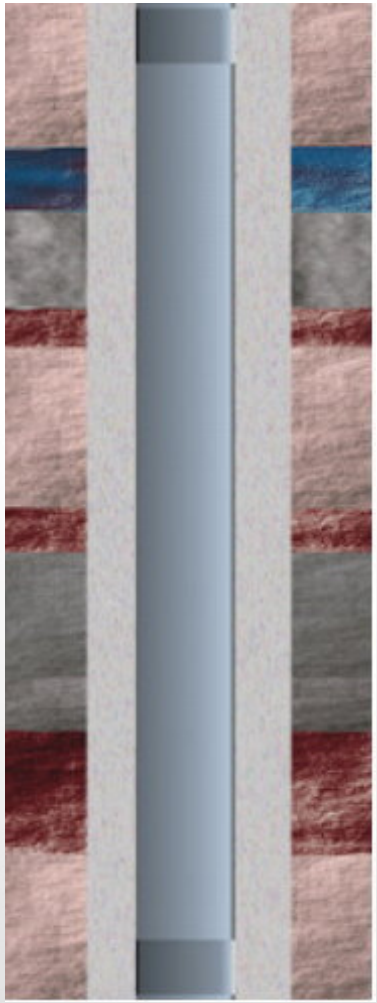
Examples of Non-Routine abandonments are:

- wellbore problems such as; fish in the hole over two porous zones, a leaking plug, a ghost hole across two or more formations
- re-abandonment of a well
- surface abandonment where cement doesn't cover all ground water zones
- planned use of cement plugs that do not meet regulatory requirements
- setting of a plug not meeting regulatory requirements

BASE OF GROUNDWATER PROTECTION

Base Groundwater is defined as any water strata with a Total Dissolved Salt (TDS) content less than 4000 mg/litre

- Any useable aquifers which are not covered by the Surface Casing or which are above the cement top on the production casing will require remedial cementing operations to isolate from hydrocarbon sources and/or other protected intervals



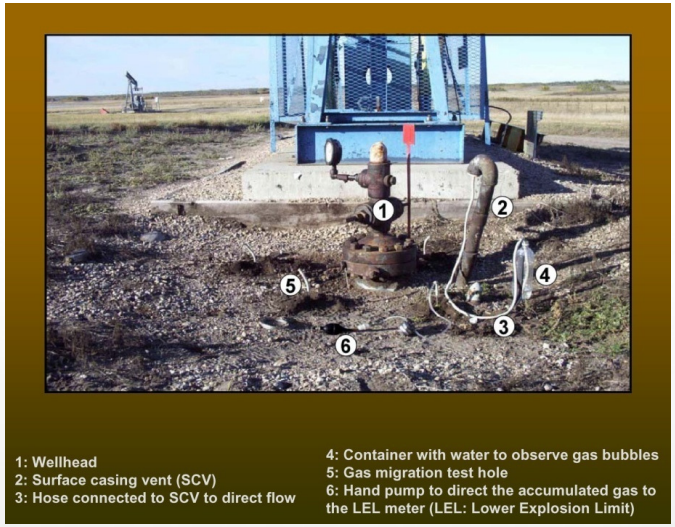
GAS *LEAKS*

Sustained Annular Casing Gas (Surface Casing Vent Flow)

- Surface Casing Vent Flow is the flow of gas and / or liquid or any combination out of the surface casing / casing annulus
  - A failed SCVF test may be as low as one bubble in 10 minutes

Gas Migration

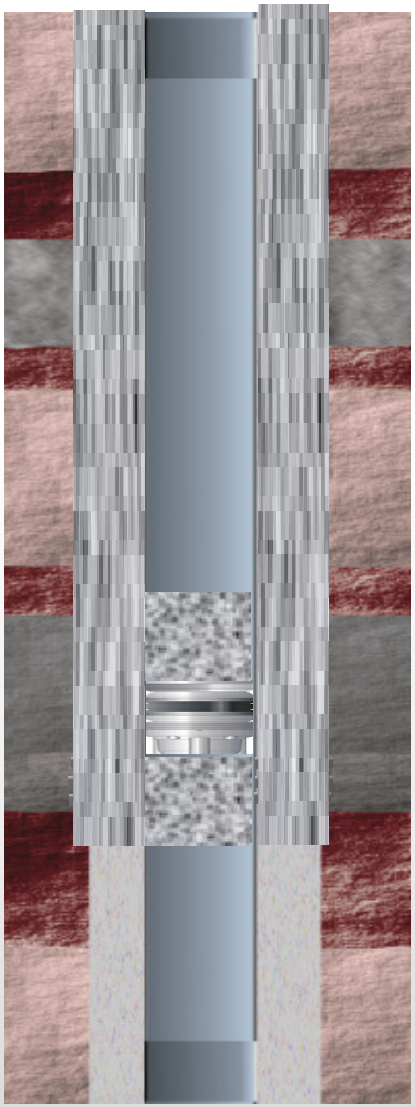
- Gas Migration is the flow of gas that is detectable at surface; outside the outermost casing string
  - Source may be either above or below surface casing shoe

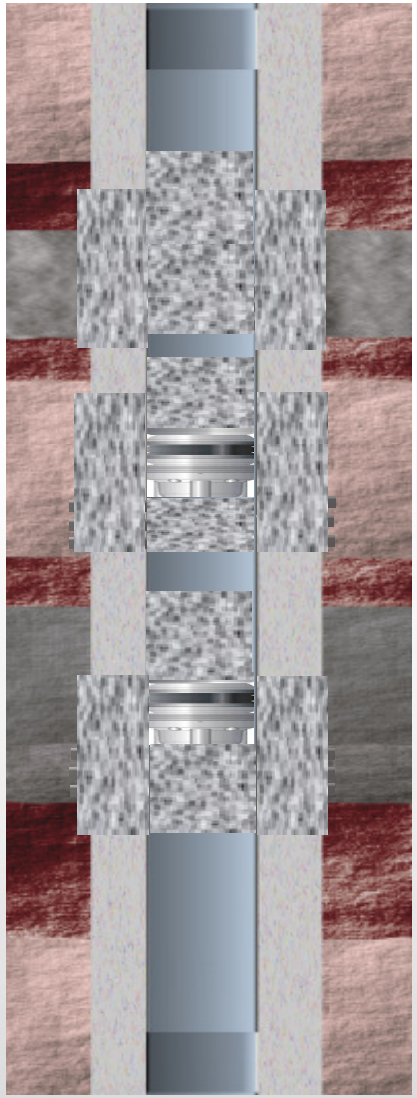


REMEDIAL CEMENTING REPAIR

- Formation access via removing casing, perforating, milling or slotting casing
- Remedial cementing with either circulation to surface or
- If circulation not achieved, but feed-rate established, cement squeeze must be completed using multiple perforations and remedial squeezes, without exceeding the formation fracture pressure.

Operator must evaluate wellbore to ensure all protected intervals above the BGWP are isolated from each other.

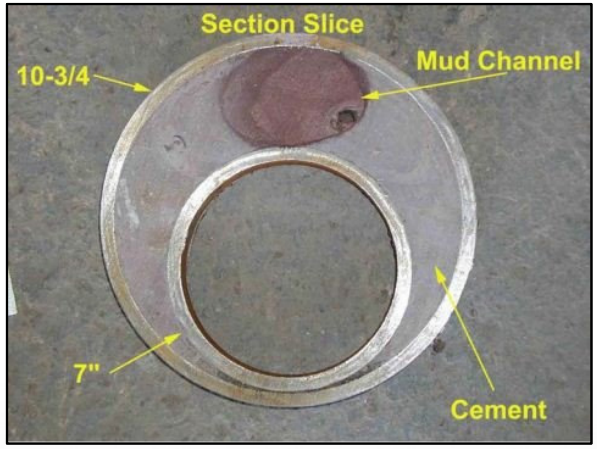




GAS TRAVEL THROUGH CEMENT SLURRY

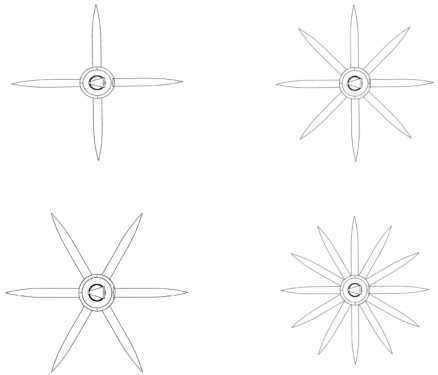
Cement loses ability to hold hydrostatic pressure during transition from slurry to gel

- After cement placement do not release pressure
- Use retainer
- Maintain artificial hydrostatic after squeeze
  - Allows for gas to channel



PRESENT PERFORATING METHODS

- Perforating phasing has an impact on the connectivity of cement sheath and formation



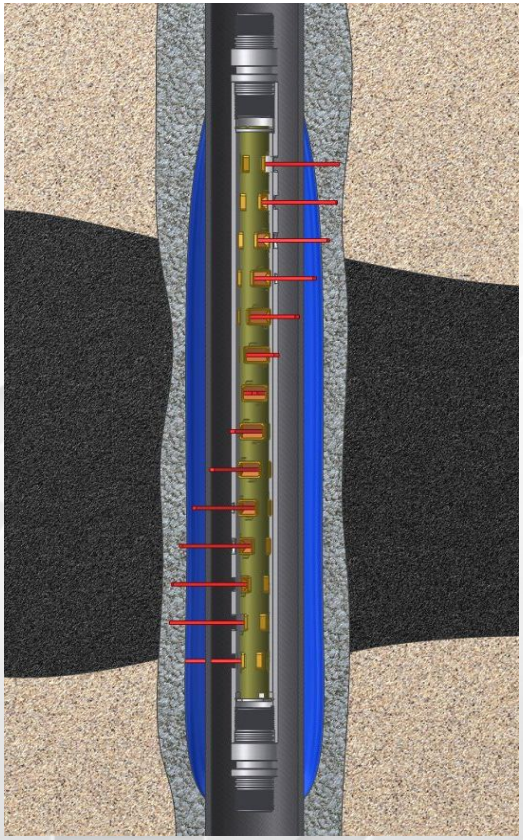
- Shaped Charge type has an impact on the perforating channel geometry. i.e. DP, BH or Reactive Liner

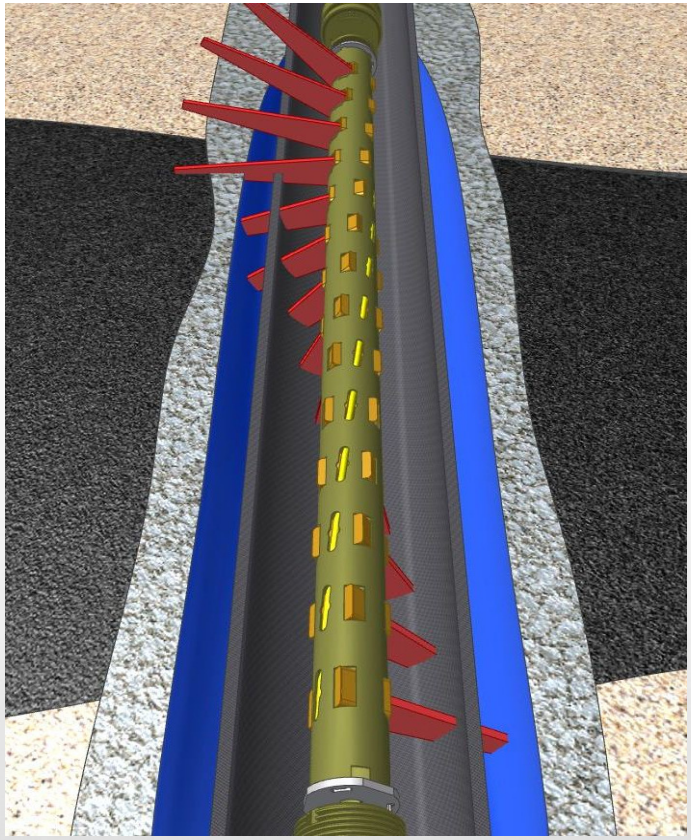
Alternate Methods

- Abraza-jetting – can achieve 480 º coverage within 1 m

- Section milling totally removes the casing

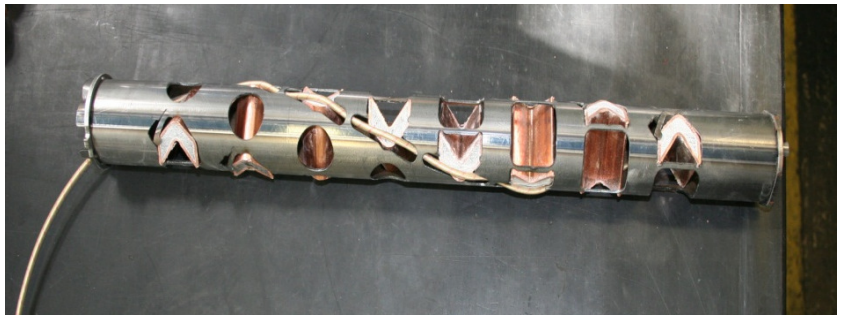
ALTERNATIVE PERFORATING METHOD: SLOTTED-CHARGE PERFORATING GUN SYSTEM

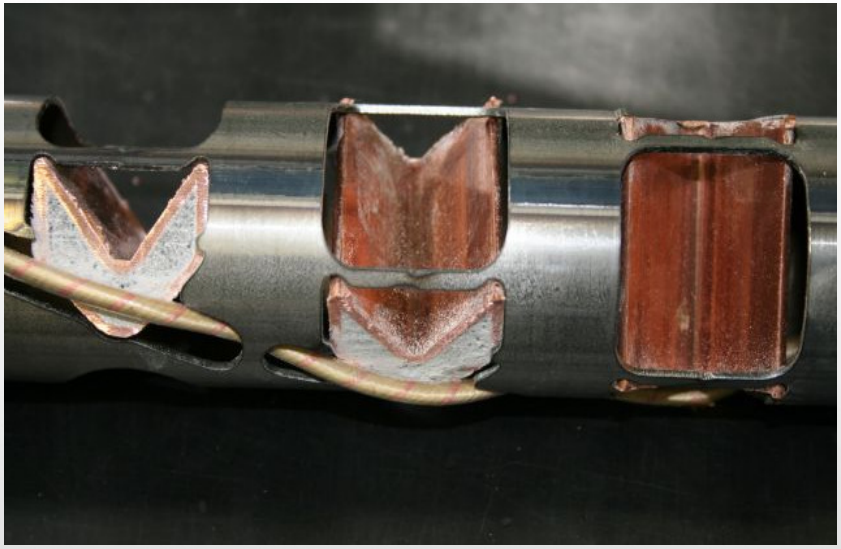




PERFORATING SYSTEM DESIGN

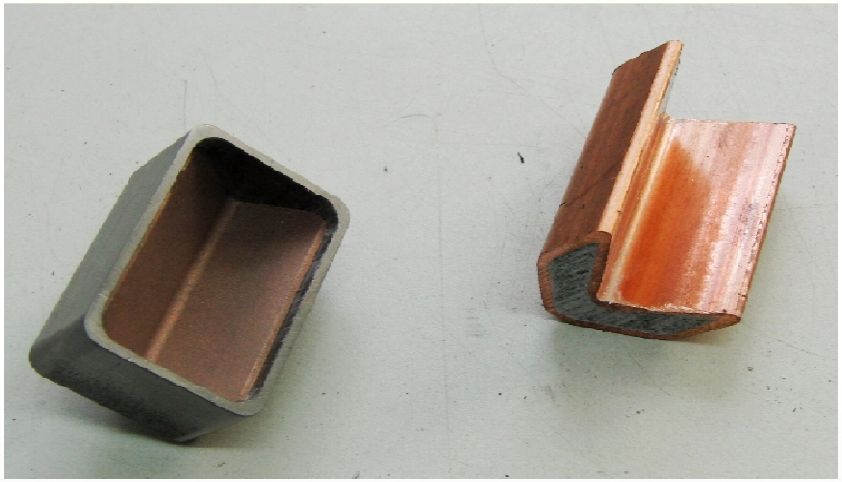
- Standard Linear Shaped Charges
- Unsuitable for this application
  - Insufficient or non-perforation of slots in casing
  - No control of charge design

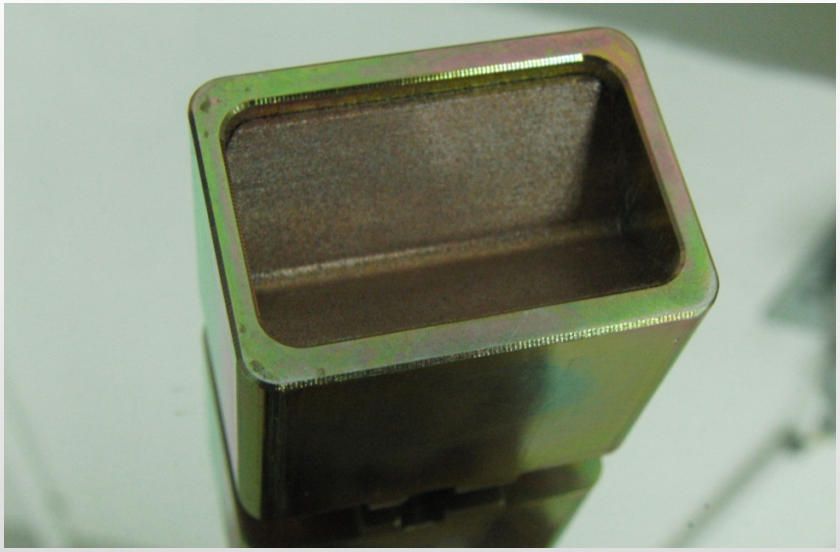




PERFORATING CHARGE DESIGN

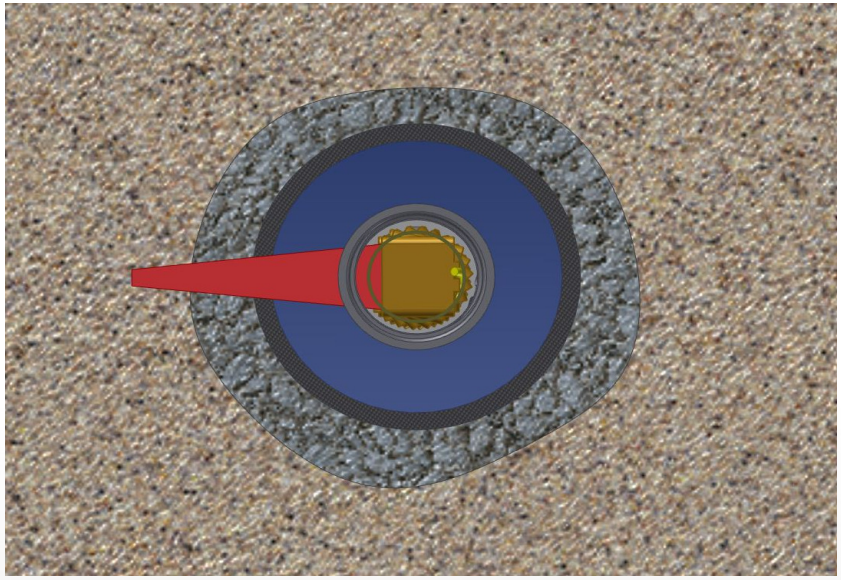
- Rectangular Shaped Charge
- Liner Geometry
- Liner composition
- Point of initiation
- Integrate to standard perforating hardware





PERFORATING: SINGLE SHOT TESTS

- 30g HMX-St Slotted Charge
- 86mm-13spm-20º for 4 ½“ to 5 ½“ Casing
- Penetration: ~6 inches in concrete.
  Difficult to measure accurately due to target shattering



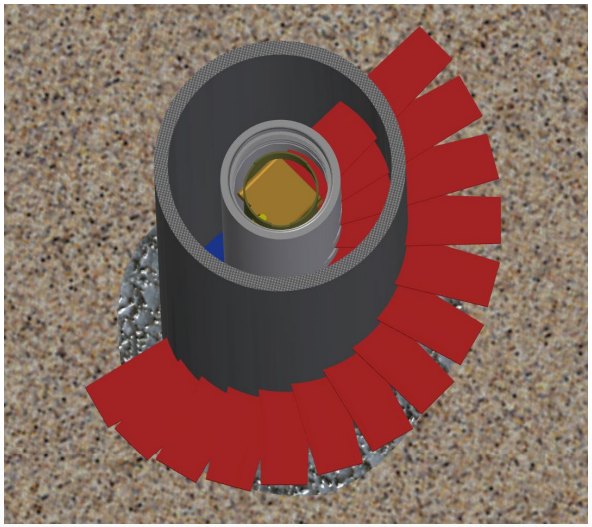
PERFORATING GUN SYSTEM

Zonal Isolation:

- 360°circumferential access to the annulus between casing and well
- Provide access to voids in the previous cement job and formation

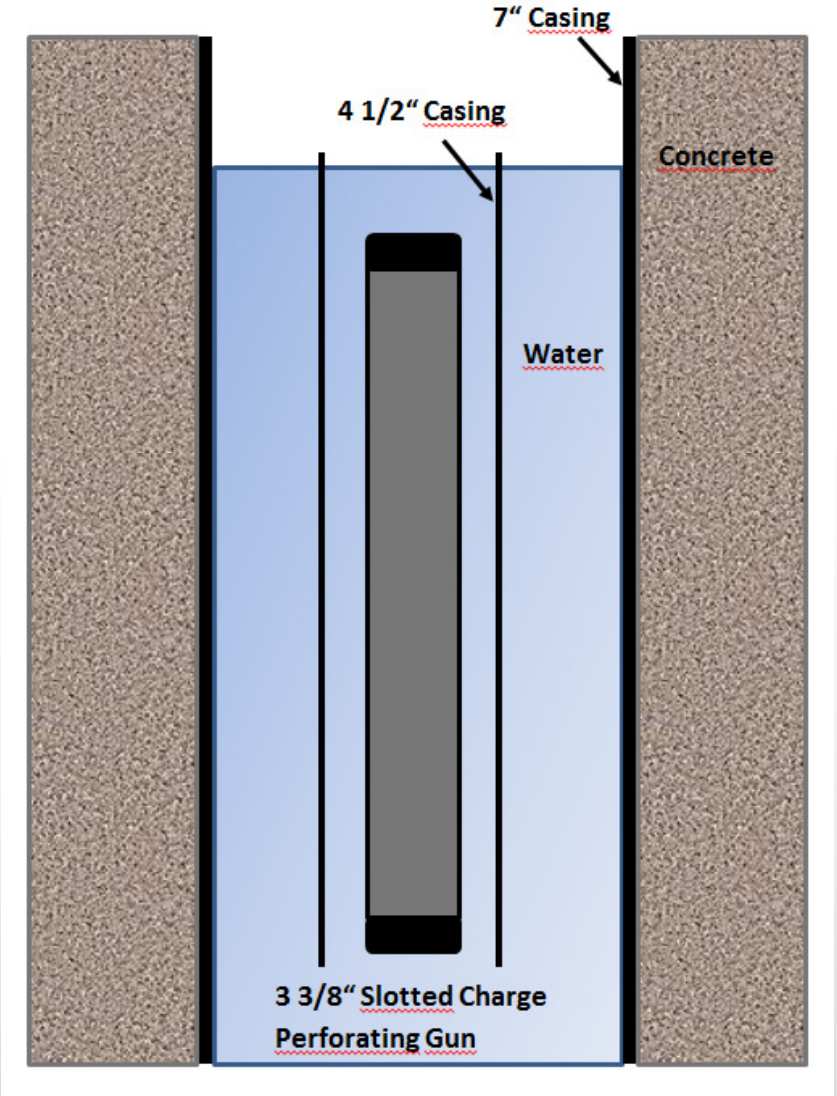
Multiple Casings:

- Perforation is restricted to inner lying casing
- Create rectangular slots in inner casing with no damage to outer casing

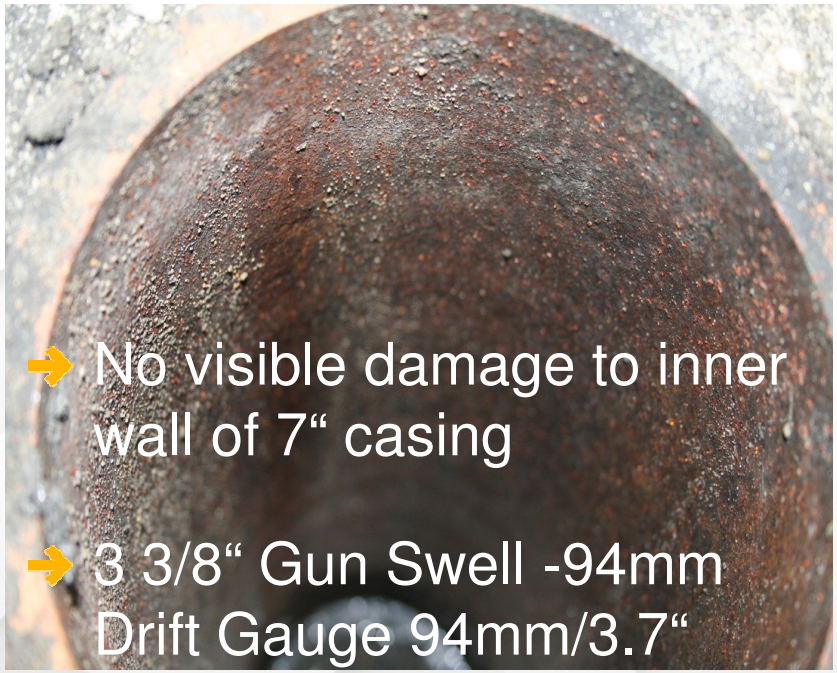


TESTING OF CASING INTEGRITY

- Reference test set-up to confirm limited entry and no perforation of outer casing
- Gun 3 3/8“-4spf-20°
- 4 1/2“ (11.6 lbs/ft) Casing inside 7“ (32lbs/ft) L-80 Casing

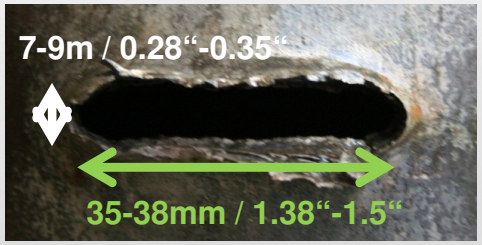


TESTING OF CASING INTEGRITY



- No visible damage to inner wall of 7“ casing
- 3 3/8“ Gun Swell -94mm Drift Gauge 94mm/3.7“

- 18 shots (4.5ft) required for 360º helix perforation
- Overlap from slot to slot in 4 ½“ casing ~ 18mm (50% of width)

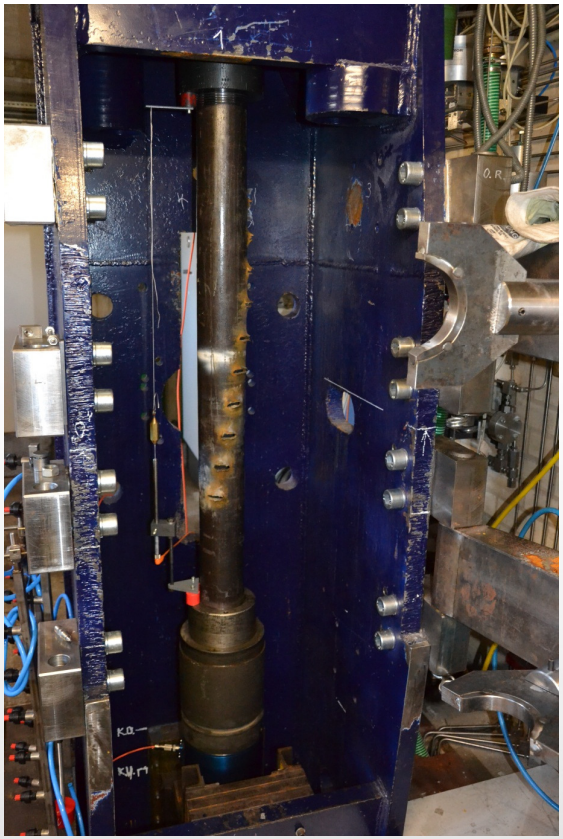


TESTING OF CASING INTEGRITY

Properties and condition of casing pipe (L 80 with 11,6 lbs/ft) after perforation:

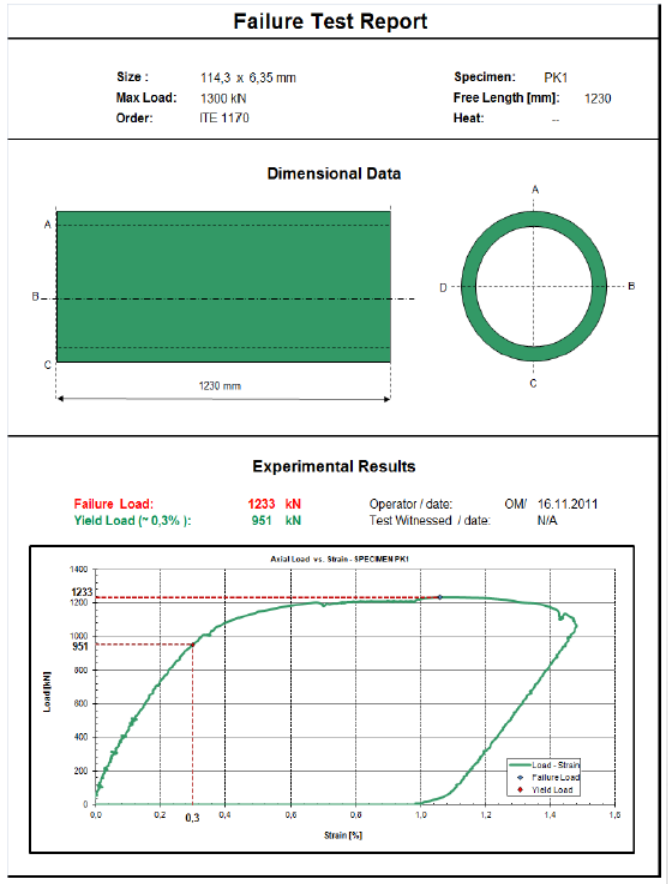
Yield Strength Testing

- Clausthal University (ITE)
  Institute of Petroleum Engineering
- Computer controlled test frame with displacement sensor
- Free length of 4 ½“ casing in frame 1230mm
- Maximum load of test frame is 1300KN



TESTING OF CASING INTEGRITY

- Visible widening of perforated slots from tensile test
- Loss in tensile strength in casing ~11%
- Loss in yield strength in casing ~15%



RESULTS OF FIRST FIELD TESTS

3 wells were perforated using 3 3/8“ guns of 1.3m length with 18 charges each to cover 360°

#1: Perf interval 248,0m – 250,8m

- Job needed acidizing to pump cement
- Well monitored for 2 months w/o gas migration

- #2: Perf depth 680m
  - No cement could be displaced
  - Re-perf in different zone with BH charges allowed successful cement job

- #3: Perf depth 302m
  - After exceeding anticipated squeeze pressure well was cemented
  - Well monitored for 2 months w/o gas migration

VIDEO OF SLOT PERFORATION (JOB #1)

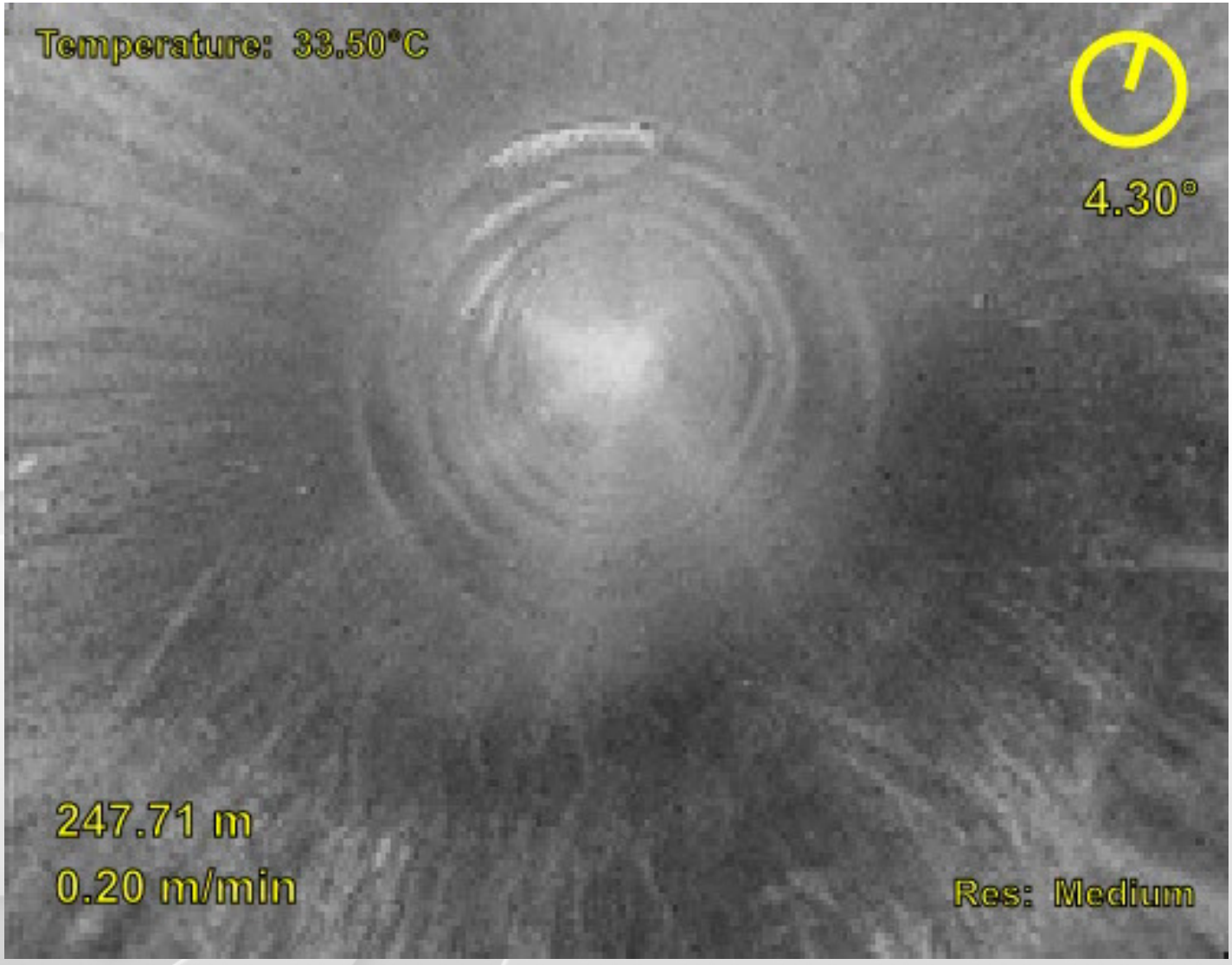
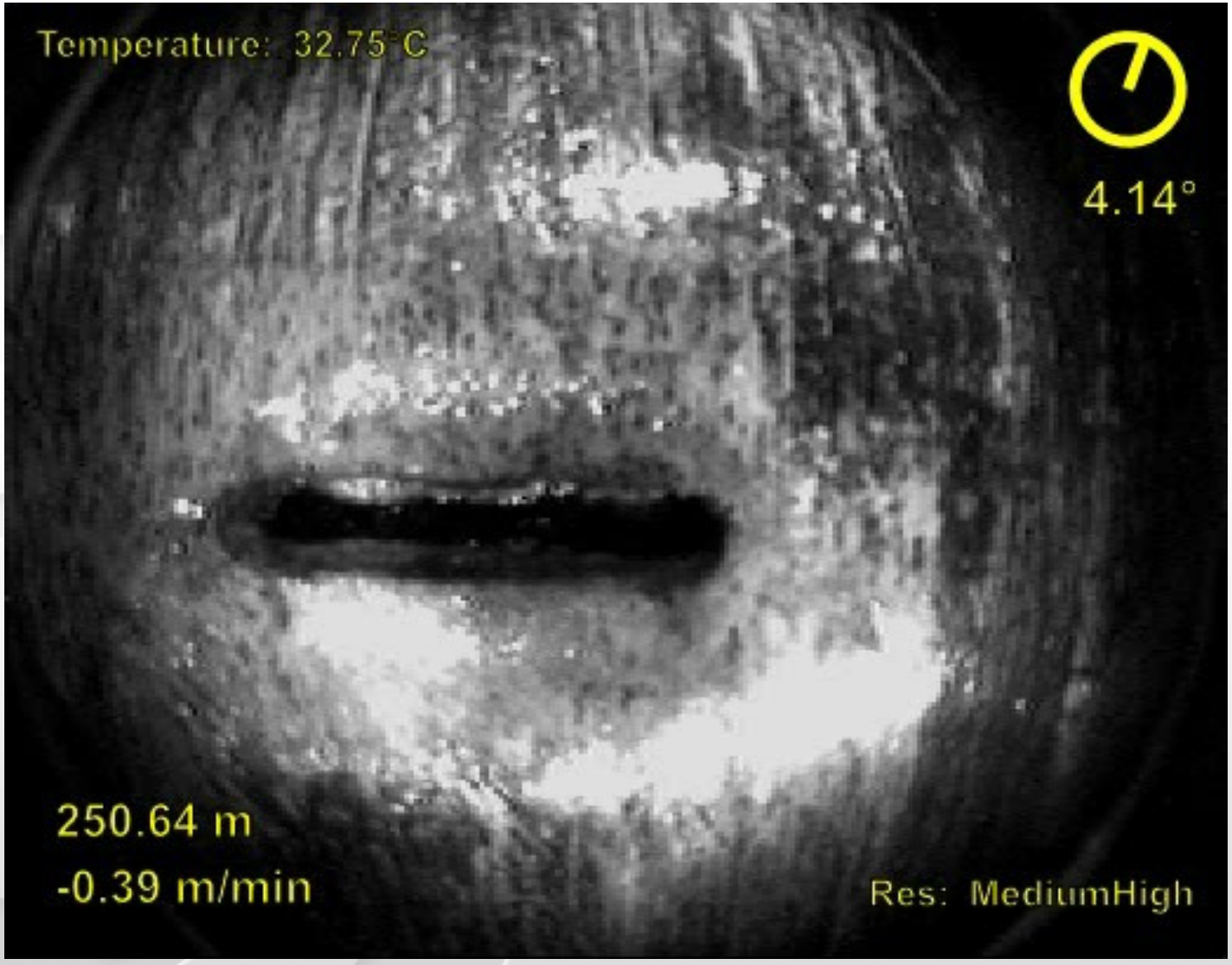
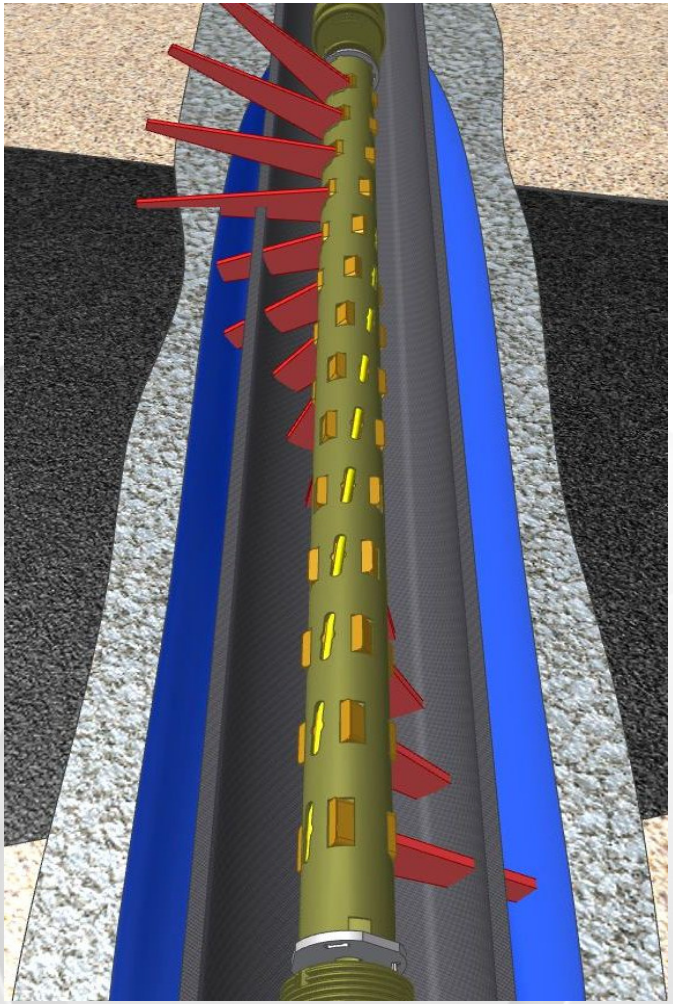


IMAGE OF SLOT PERFORATION (JOB #1)





Thank you.

Questions?